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SPACE STATION AS A LONG DURATION EXPOSURE FACILITY

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ABSTRACT

There is need for a space platform for experiments investigating long duration exposure to space. This platform should be maintainable in the event of a malfunction, and experiments should be easily recoverable for analysis on Earth. The International Space Station provides such a platform.

The current Space Station configuration has six external experiment attachment sites, providing utilities and data support distributed along the external truss. There are also other sites that could potentially support long duration exposure experiments. This paper describes the resources provided to payloads at these sites, and cites examples of integration of proposed long duration exposure experiments on these sites. The environments to which external attached payloads will be exposed are summarized.

INTRODUCTION

Many materials and systems used in Space Station design are applications from LDEF results and other unmanned missions. The Space Station program is currently planned for a 10 year operational lifetime with the option of extending it to 15 years. As a result, the station has the potential to be a valuable resource for long duration exposure data.

This paper will discuss the current Space Station design, as it relates to space exposure science, and the importance of early data collecting in maximizing science return capabilities of the station. The accommodations for space exposure experimenters will be presented, including the baseline attached payload sites and the resources provided to users, and an Express Pallet concept, similar to the Space Shuttle's Get Away Special program.

1.0 SPACE STATION TECHNOLOGY EXPERIENCING LONG DURATION SPACE EXPOSURE

Many of Space Station's designs are applications of LDEF results, and have the potential to be valuable resources for long duration exposure data in an active spacecraft application. The environments of an active spacecraft are more complex and will impose different effects than a passive space platform on the exposed technologies applied. Early measurement and experimentation with these station-unique designs would be valuable to assessing life limits and planning maintenance approaches to maximize performance of the Station's systems and extend its lifetime.

Fig. 1 indicates the designs for which there is interest in measuring environmental effects and which will be discussed in this paper. Alternate design concepts are still being evaluated at the time this paper was published, and the figures presented are only examples. No matter what configuration may be decided upon, many elements, common to all configuration concepts, will require protective material coatings to preserve longevity by passively controlling thermal environments. Material coatings are susceptible to optical property degradation due to atomic oxygen (AO) and ultraviolet (UV) radiation sensitivity, which can result in degradation of system performance. Among those used on Space Station are:

- Sulfuric Acid Anodized aluminum structure. The anodize keeps the truss in a medium temperature range, required for EVA operations.

- Yellow Dyed Anodize on EVA handrail. This anodize provides medium-range temperatures and visibility to EVA astronauts.

- Z-93 inorganic zinc oxide based white paint[1]. This thermal control paint is used on the Active Thermal Control System (ATCS) radiator panels for its low absorptivity and high emissivity.

- Silver Teflon thermal control tape. This is used on the radiators of the mobile transporter for its low absorptivity and high emissivity.

Micro Meteoroid/ Orbital Debris shielding is used on several critical Space Station elements to protect them from damage caused by micro meteoroids and by orbital debris impacts. The standard design for these elements is the aluminum Whipple shield. This will be applied for protection of the ATCS pump modules and ammonia tank modules, the pressurized mating adapter, airlock and the cryo tanks. Nextel®, an aluminum boro-silicate fabric manufactured by 3M, is under consideration for shield design. It is much lighter and can defeat a 30% larger particle than an aluminum shield of similar design[2]. Space Station offers the opportunity to develop advanced shielding concepts such as Nextel®.

Space Station systems are yet another area where the LDEF program has influenced the design. LDEF showed good performance of fiber optic systems in the space environment, and recoverability of performance after an inactive state. Fiber optic systems offer data management systems increased data traffic over traditional twisted shielded pairs and will therefore be used for the high level of expected payload data and communications. The greatest losses of these systems are in the connections. However, McDonnell Douglas Aerospace (MDA) has developed several advanced connections designed to minimize signal loss, including a hermetically sealed

[1] Manufactured by the Illinois Institute of Technology Research Institute (IITRI)

[2] IRAD report MDC 91H0515, "Test Results for Alternative Orbital Debris Shield Concepts."

dual-side connector for the pressurized volumes. The glass fibers, light-emitting diodes and the connections are considered together as an interdependent system.

2.0 SUMMARY OF SPACE STATION ENVIRONMENTS

The Space Station is planned for a 190-250 n-mi orbital attitude similar to that of LDEF. The environments it will experience are similar to LDEF in some respects, yet much more complicated in others due to the inherent activity involved in an active, manned spacecraft. The effects of the natural environment on system performance will be compounded by contamination contributed by Station activities.

AO flux and solar radiation levels are expected to be slightly different from that experienced on LDEF. Radiation levels increase with orbital inclination, and Space Station may be orbiting at the 51.6° inclination in order to take advantage of Russian contributions to the program. LDEF flew at a 28° inclination, where there is comparatively less radiation exposure. In addition, Space Station will be periodically reboosted to maintain a nominal 250 n-mi orbit for most of its flight, whereas LDEF started at the same altitude as Space Station and drifted lower over time. This results in less AO flux for Station than that experienced on LDEF, but the additional exposure to AO from a longer life in orbit may negate this benefit.

The Space Station will fly in a Local-Vertical-Local-Horizontal (LVLH) orientation, which provides constant viewing directions not only to users, but also to various exposed station surfaces. This requires specific elements to be designed with micro meteoroid and orbital debris protection. This is key, since Space Station will experience increased orbital debris density over LDEF due to the increased space satellite traffic a decade later.

The Space Station, in contrast to LDEF, is an active spacecraft with regular interfaces with the Space Shuttle Orbiter and other activities which affect the design. The program has responded, where practicable, to minimize the contamination of exposed surfaces resulting from these activities. The responses are summarized as follows:

- Orbiter proximity operations, including mating and demating to Station, involve the Orbiter Reaction Control (RCS) System thrusters to control its trajectory. The emitted propellant is directed toward Station hardware, resulting in deposition buildup on surfaces. Of more critical concern, however, are the RCS thruster plumes directed at the large Solar Arrays, threatening structural damage. To avoid such a catastrophic event, the Solar Arrays will be oriented in a "feathered" position to the RCS jet stream, during orbiter proximity operations, minimizing loading on the array mast.

- Plasma Contactors will be installed on the center Truss Assembly to significantly reduce the ion sheath impedance and related high structure floating ground negative voltage potential occurring as the Space Station travels through the ambient plasma. This is accomplished by emitting electrons to reduce the Ion sheath impedance thereby reducing, or eliminating, the negative voltage potential on the Space Station structural members.

- Periodically, waste fluids will be vented from the internal environments. These fluids may potentially stick to external surfaces or cause ice bridges between elements. This problem can be alleviated through proper alignment of the vents in the design process.

Some operations' contamination effects may be minimized with planning, but not all operations can be controlled. The Russian Tug is planned for reboost and it is directed aft of the Space Station. However, in the space vacuum, the exhaust plume tends to expand and curl around nearly 180° back on itself; so some contamination to surfaces is expected, and must be considered in the overall assessment. Also, outgassing from all station hardware contributes to contamination of Station surfaces.

3.0 ENVIRONMENTAL IMPACTS ON SPACE STATION BASELINE DESIGN

Contamination can be reduced by careful planning, as discussed above, but not eliminated. It will compound the problems imposed by the natural space environment. Solar radiation, extreme thermal cycling, AO and contamination all work together to degrade system performance of Space Station elements. The synergistic effects of these degrading influences need to be evaluated as follow-on experiments from pure test article to application. Program requirements specify the contamination limit from all sources to be 100 Å deposition/year[3].

Table 1 presents the impacts of the space environment on sensitive materials and systems used in the Space Station design. The materials were chosen based on LDEF experience and data from other unmanned programs.

Table 1: Environmental Impacts on Space Station Baseline Design

Exposed Material	Environmental Concerns
Sulfuric Acid Anodize	UV Radiation, Spacecraft Contamination, Resulting in Absorptance Increases
Yellow Dyed Anodize	AO or UV can Bleach the Coating
Silver Teflon Tape	AO Erodes the Teflon. Contamination Could Affect Optical Properties. May see Thermal Expansion Difficulties with the 10 mil Tape.
Z-93 Paint	Contamination, Impairing Optical Properties
Optical Fiber Systems	Solar Radiation Darkening Glass, Resulting in Signal Loss.
Nextel® Shielding	Upon Impact, Nextel® Sheds Particulates, Posing Potential Hazard to Crew.

- Sulfuric Acid Anodize, used on the truss to maintain medium range temperatures, is UV sensitive, and its optical properties respond by increasing absorptance. This effect is compounded by the contamination resulting from proximity operations, system vents and outgassing of surrounding elements.

- Yellow Dyed Anodize on EVA handrails will become bleached when exposed to AO or UV, thereby reducing visibility and affecting its ability to maintain medium range temperatures.

[3] SSP-30426, Rev. B, July 1991, "Space Station External Contamination Control Requirements."

- Silver Teflon thermal control tape is required on the mobile transporter radiators due to the low absorptivity and high emissivity. AO degrades the Teflon in the tape, damaging its integrity. Contamination could impair the optical properties of both these elements, affecting their radiative performance. In addition, the silver Teflon tape has never been flown using a 10 mil thickness (5 mil thickness has substantial flight experience): the extreme thermal cycling of the space environment could cause cracking.

- Z-93 white paint is used on the large thermal control radiators for its low absorptivity and high emissivity. Contamination buildup on these large surfaces could impair the optical properties of the paint, reducing heat radiation efficiency.

- Inactive optical fiber systems darken due to solar radiation, resulting in signal loss. However, performance fully recovers when reactivated. Fiber optic communications on Space Station will be active and inactive, as mission requirements demand. Although system performance recovers once the system is activated, the long-term effect of these cycles is not known and warrants measurement. The greatest loss is expected in the terminations due to contamination upon assembly, many of which are designs unique to Space Station.

- Space Station offers the opportunity to develop advanced shielding concepts to defeat micro meteoroids and orbital debris. Nextel® is one option as a replacement for aluminum in the shield design. Although Nextel® can defeat larger particles than a similar aluminum shield design, it sheds particulates into the immediate environs upon impact and these glass particles can obstruct viewing and find their way into the pressurized modules, posing a health hazard to the crew. Teflon coating is an option currently under consideration for reducing the particulate shedding.

All the above are good candidates for early experimentation to determine performance stability and degradation over time. For example, several small material samples of the Sulfuric Acid Anodize, Yellow Dyed Anodize, Z-93 paint and Silver Teflon thermal control tape could be pre-integrated into the structure and deployed. Partial retrieval at six month intervals to measure progressive effects over time would augment the two-point data - initial condition and final condition - developed by LDEF and other unmanned experiments. . Optical fiber systems can be tested by appropriate instrumentation or by a small, cycleable, closed, active system pre-integrated into the structure. A sample of Nextel® shielding, with and without Teflon coating, would be valuable to assess its performance life and particulate shedding. Additionally, dopants, or coloring agents, can be added to the Nextel fabric which give it various thermal control properties, depending on the dopant used; and samples of these dopants in Nextel® should be tested in the space environment. Early data gathering and assessment will increase the accuracy of Space Station's life certification and maintenance scheduling, which could lead to pre-planned product improvements.

4.0 EARLY EXTERNAL EXPERIMENTATION OPPORTUNITIES

There are opportunities for pre-integrating experiments into the truss early so that experimental data may be derived as early as possible, making Space Station a working laboratory for external science upon deployment, and maximizing Space Station science return. Figure 2 indicates potential attachment sites that may be used in the earliest assembly stages. The Russian Universal Docking Joint and the Nadir port of Node 2 are reserved for additional pressurized modules to be manifested a few years into the Station program, and are therefore available for pre-integrated payloads prior to that time. The Russian Tug is a modified Kvant vehicle which has 3 external payload ports available on the Nadir side. The truss extension leading to the advanced Solar Power Module (SPM) may provide excellent viewing to pre integrated payloads. These locations have varying resources for payloads.

Distributed systems incorporated over much of the infrastructure offer temporary sites in the early stages of assembly whereby experiments may be pre-integrated and initiated upon deployment prior to full station operation, as determined by mission planning. There are several camera mounts, but only 4 EVA cameras, which will be used during an EVA intensive activity. Each mount has structural attachment, with guide pins and bolted attachment, and provides power and data interfaces. Similarly, the Remote Manipulator System (RMS) grapple fixtures are used for remote assembly purposes and are available thereafter, providing power and data to an on-orbit assembled payload. The Portable Foot Restraint sockets are used during EVA missions and provide only structural attachment. Utility Distribution System tray breakouts are power sources, nominally used to power the RMS. These options are offered as early opportunities only in the 1997 - 1999 time frame, when the attached payload accommodations in the outboard truss segments become active, as discussed in the next section.

These alternative payload sites can accommodate small, LDEF-type experiments which require minimal or no power and data handling capabilities. Larger payload facilities with more complex resource requirements, such as the Cosmic Dust Collection Facility proposed by JSC, can be accommodated by the baseline Attached Payload Accommodations. These external attachment sites provide Station power and fully integrated data handling resources, as well as serviceability, in a variety of integration options, as discussed in detail in the next section. The variety of experiment concepts provides the opportunity to make full use of Space Station's capabilities as an orbiting space laboratory, which not only can help assess its own designs, but also get experimenters on board as soon as possible.

5.0 SPACE STATION ATTACHED PAYLOAD ACCOMMODATIONS

Prior to the Space Station Redesign, the Space Station Freedom design included four Attached Payload ports on the US truss: two on the starboard side on the back face and two sites on the front faces of the port side. The two starboard sites were available to become active at the Manned Tended Configuration (6/97) and the two port side sites would become active by Permanent Manned Capability (6/00).

Currently, on the redesigned International Space Station Alpha (ISSA), there are up to eight attached payload port sites on the US truss (See Figure 3)[4]. These sites provide external payloads with a standard interface, viewing in all directions, adequate resources and flexibility to

[4] The Redesign of the Space Station is a continuing process. The Figure presented is for reference only, and should not be considered the final Space Station design.

accommodate a variety of payload classes (e.g., large, complex to small, simple payloads). There are three sites on each of the starboard and port truss segments located inboard of the Solar Power Modules (SPM's). In the ISSA configuration the port sites may become available in early 1999 and the starboard sites may become available in mid 1999. An additional two attach sites may be located on the truss of the starboard SPM. However, the sites inboard of the solar arrays provide better overall accommodations (e.g., ease of access, data management, payload mass and volume), and these are considered the primary locations.

In general, attached payload accommodations are improved over the Freedom Design. Each Attached Payload port provides standard utilities and a robotically compatible attach mechanism. The Station can provide up to 3 kW of power from redundant sources to each site and a total of 6 kW aggregate for all sites. Attached payloads will still be required to provide their own thermal control. Data accommodations are provided by 1553 local bus service and a connection to a High Rate Data Link (HRDL). Access to the HRDL increases the maximum data down link capability from 400 Kbps to 43 Mbps. Attached payloads will be installed and serviced using the Space Station RMS and dexterous manipulator with EVA backup. The shortage of EVA time requires that external payloads be as robotically compatible as possible. The Space Station will provide accommodations to integrate, operate and service attached payloads on a regular basis.

The attachment mechanism for external payloads remains the standard Space Station mechanical attach structure, or Attached Payload Attach Structure (APAS). The redesigned Station configuration may offer the ability to pre-integrate the APAS to the truss for launch and the increased payload capability of 11,500 pounds. This combined with a slightly larger operational envelope allows larger payloads to be accommodated. Figure 4 demonstrates full loaded APAS's on the port side. The view of the Station is from the front, looking down on the Zenith sites. It shows two attached payload pallets between the photo-voltaic arrays and the thermal radiator, and the Inboard lower attach location is dedicated to the Unpressurized Logistics Carrier (ULC).[5] Each site offers flexibility in experiment size, attachment concept and utilization.

6.0 SPACE STATION EXPRESS ATTACHED PAYLOAD PALLET CONCEPT

The EXPRESS Payload Program has been initiated to support the Space Station external payload program. The Expedite the Processing of Experiments to Space Station (EXPRESS) Program will provide the capability for an accelerated and simple integration process for externally mounted payloads. The goal of the EXPRESS Payload Program is to reduce the cost and time associated with the small, rapid response payload development, operation and integration. To accomplish this, small payload accommodations hardware and a streamlined integration process must be developed. Exposure science experimenters will find these smaller, standardized carriers an efficient vehicle for integrating their experiments onto the APAS in order to take advantage of the power, data and communications capabilities of the attached payload sites. Many smaller payloads may be accommodated on one APAS to maximize the use of the site. Standardization of payload interfaces and certification of payload carriers are a key feature of the EXPRESS Program.

The EXPRESS Attached Payload Program Study was sponsored by NASA to define an attached payload EXPRESS Program including carrier concept definition, integration process, and associated costs and schedule. The EXPRESS Attached Payload Program is modeled after

[5] Note: final number and configuration of the attached payload sites and ULC locations under study at time of publication. The platforms displayed in Figure 4 represent a concept for EXPRESS Attached Payload Pallets and are not meant to represent any actual payload manifest.

the EXPRESS Rack Program and Space Shuttle Get-Away-Special concept. The objective is to develop an EXPRESS Attached Payload platform that can support the accommodation and integration of EXPRESS Attached Payloads in less than one year.

Under the study, MDA considered the use of existing Space Shuttle and Space Station Freedom equipment capabilities to minimize development cost. Also considered were the existing attached payload operational envelopes, Space Station Logistics Elements, STS hardware, and provisions for EVA and robotic servicing.

The resulting EXPRESS Pallet System (See Figure 5) provides a cost-effective, flexible pallet that incorporates standard, available hardware, and emphasizes the minimization of interfaces and integration time. The pallet consists of three main components, the EXPRESS Carrier (comparable to Rack Drawers and Mid-deck Lockers), the EXPRESS adapter (comparable to the EXPRESS Rack) and the EXPRESS Pallet (comparable to the US. Lab).

Figure 6 shows an EXPRESS Pallet with two EXPRESS Adapters mounted to the center of the pallet. The Pallet is designed to be the EXPRESS Attached Payload facility. Similar to the laboratory modules, the pallet will be launched once and remain on orbit. EXPRESS payloads will arrive on Adapters and changed out robotically.

The three segmented Pallet is a 13' 9" by 6' Aluminum Space Frame, weighs approximately 1000 lbs and can accommodate 3000 lbs of payload. The Pallet is designed to accommodate 6 EXPRESS Adapters and a total of up to 24 payloads. The Station interface is through the Attached Payload Attach Structure (APAS). The Pallet contains the attach structure passive interface (e.g., guide pins and latch bar), and the Pallet distributes secondary power and data using wire harnesses with blind mate connectors routed from the APAS to the EXPRESS Adapters. In addition to EXPRESS use, the Pallet can be modified to accommodate large attached payloads simply by removing the guide rails.

The EXPRESS Carrier depicted in Figure 5 is designed to be the equivalent to the EXPRESS Drawer or Middeck Locker. The EXPRESS Carrier will be robotically compatible and could be available in two sizes. It will be launched on the EXPRESS Adapter on the Unpressurized Logistics Carrier or directly to the STS side-wall.

The large and small Carriers are ~34" x 25" x 30" and 16" x 25" x 30" Aluminum chassis, weigh approximately 75 and 30 lbs and can accommodate ~140 and 70 lbs respectively. The Carriers are designed to accommodate one payload each. Power and data connections are made through blind mate connectors from the Adapter. Each Carrier will receive up to 420 watts of power at 120 Vdc, a 1553B Local Bus Connection and a High Rate Data Link (HRDL) fiber-optic interface. Other features include optional sides for viewing, Anodized coated sides to create custom thermal environment, heat pipes for maximum heat rejection, and micro meteoroid shielded sides for protection of sensitive instruments.

The Carriers interface to the Adapter using guide vanes and fine alignment pins. Options for using non-robotic or fixed EXPRESS carrier, or the Hitchhiker Canister are also being considered. The Carriers are designed to follow a standard integration process that requires the Payload Integration Agreement (PIA) Main Volume as the only Space Station integration documentation. The integration process starts 1 year prior to launch with the completion of the PIA.

SUMMARY

The Space Station can be considered a follow-on experiment to LDEF. Many of the Space Station's designs have taken advantage of LDEF results. Yet, advanced materials and systems used in Space Station design carry some uncertainty as to their long duration performance in the complex environment of an active spacecraft. A variety of opportunities is provided to space exposure experimenters to assess the performance of advanced technologies. Payload developers will be able to attach experiments on a variety of locations and environments on the Space Station, from small locations distributed along the truss, to the dedicated attached payload ports that can accommodate large exposure facilities. The EXPRESS pallet concept being developed will provide payload developers a cost effective method for launching less complicated experiments to get the maximum utilization from the Space Station facility.

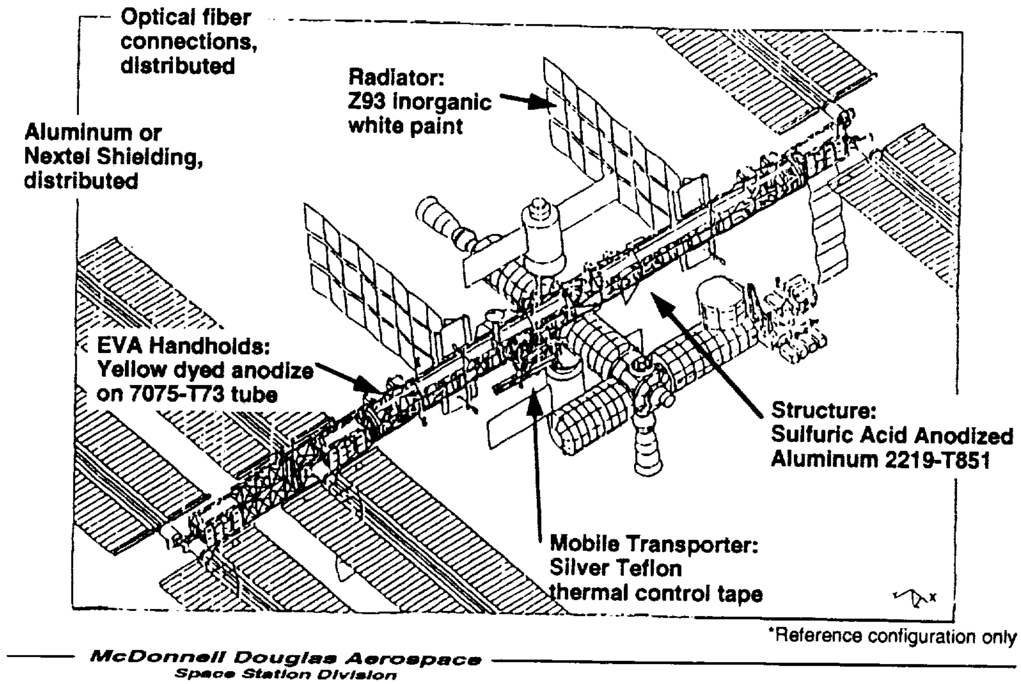

Fig. 1: Space Station is an Experiment in Long Duration Exposure

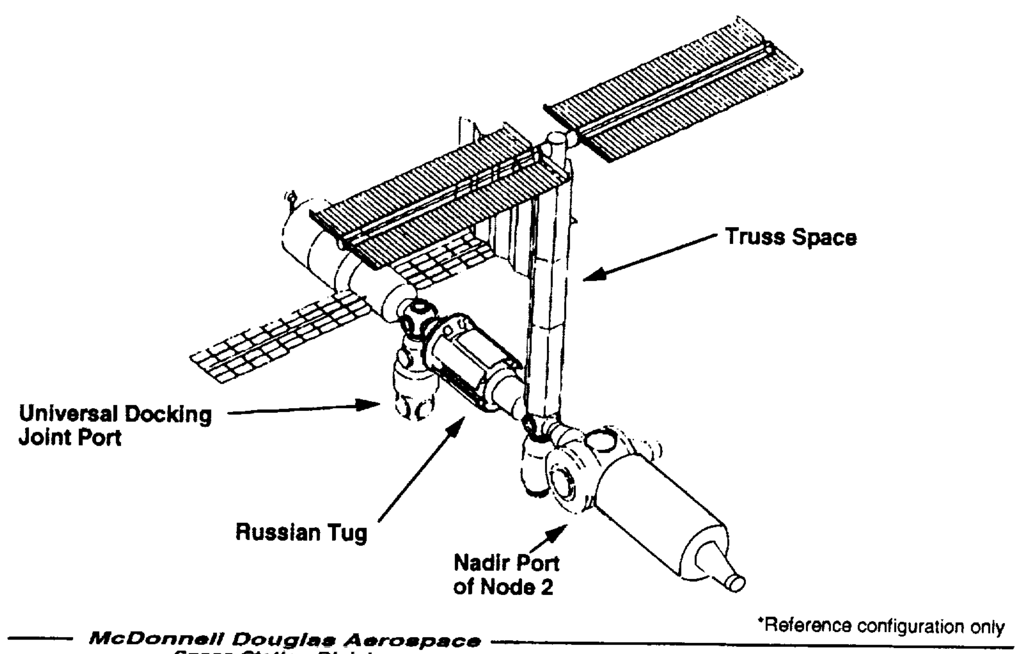

Fig. 2: Potential Early Attached Payload Sites Russian-Alpha configuration

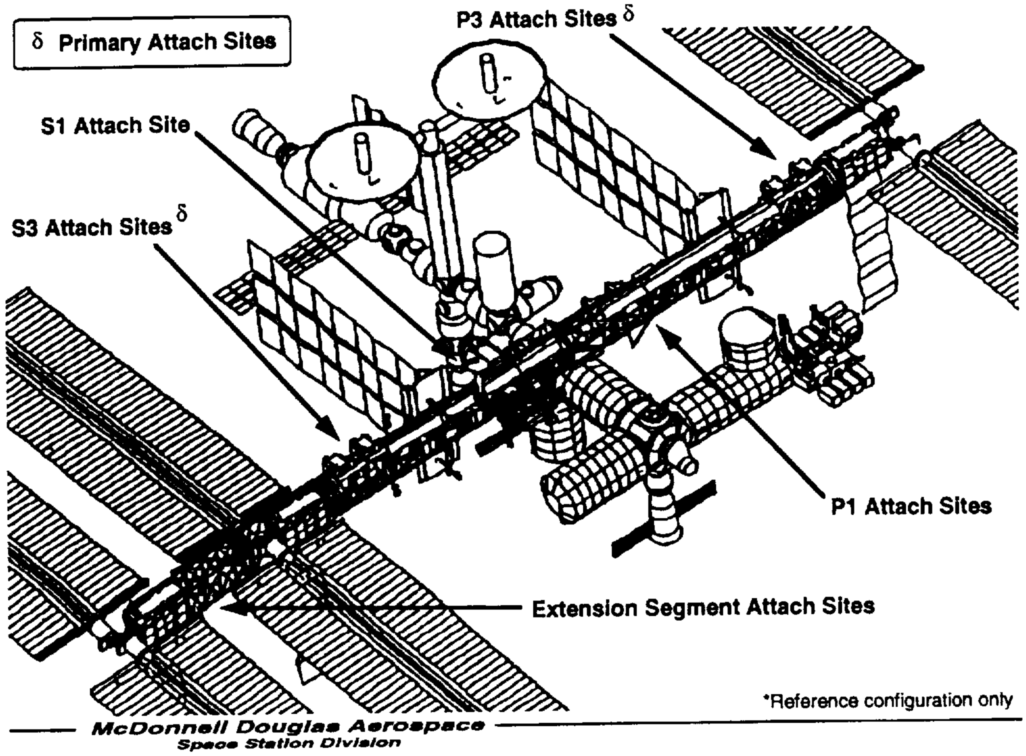

Fig. 3: Space Station Alpha Configuration with Russian Participation

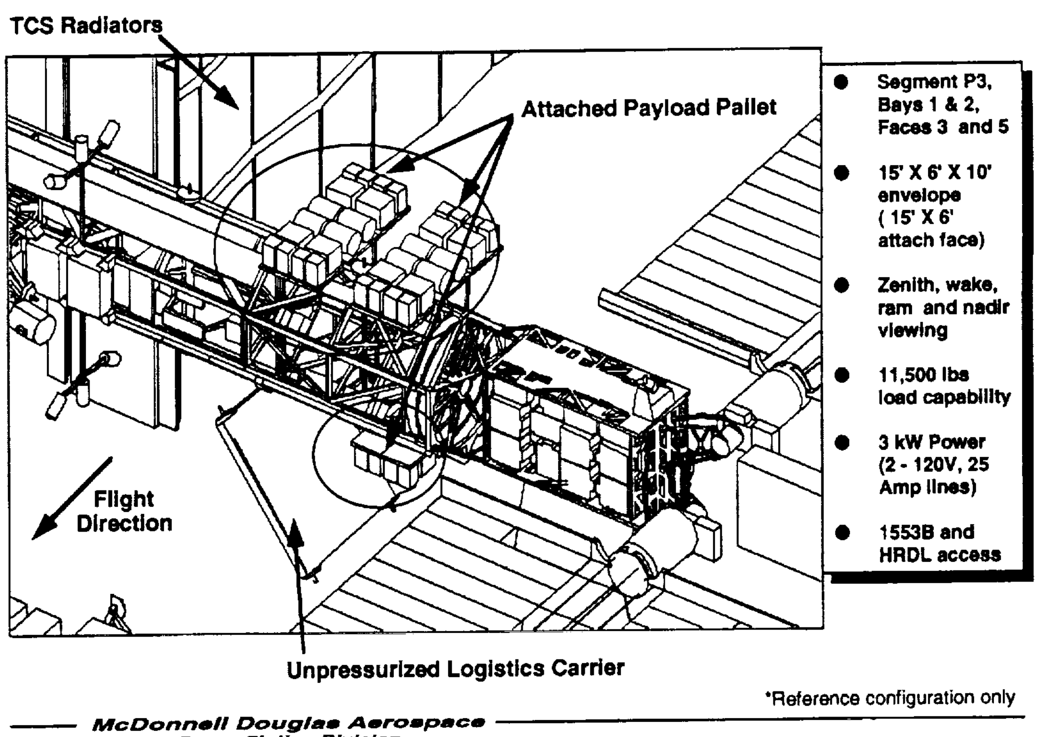

Fig. 4: P3 Attached Payload Sites

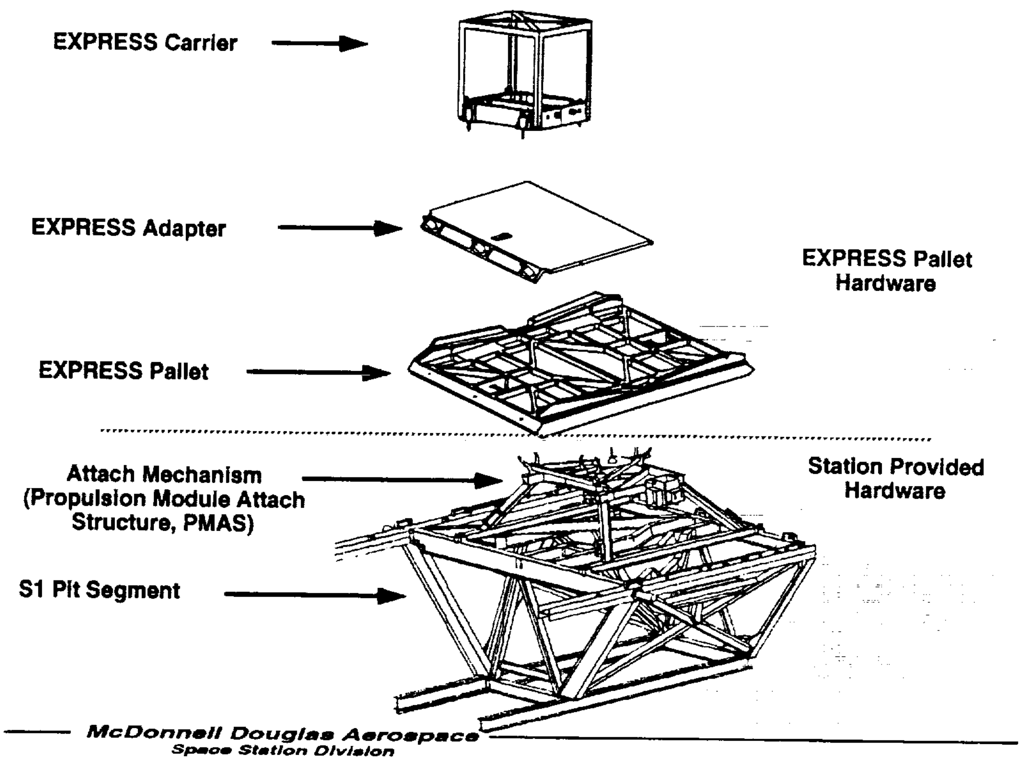

Fig. 5: EXPRESS Attached Payload Pallet Concept

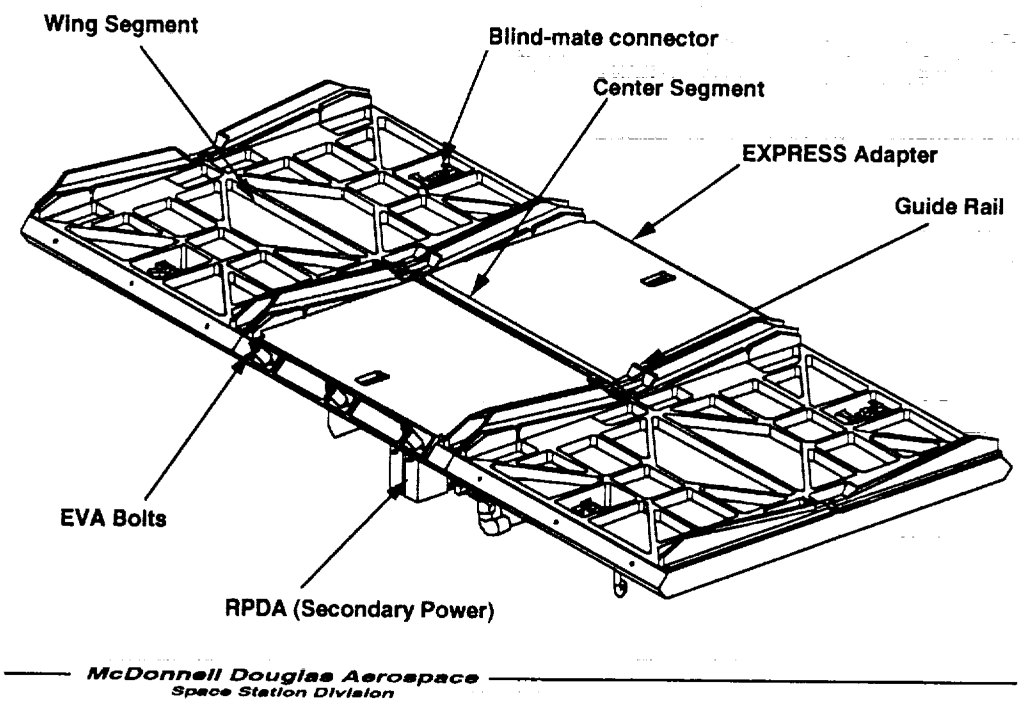

Fig. 6: EXPRESS Attached Payload Pallet